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A PRELIMINARY STUDY OF THE BENEFICIATION OF A SAMPLE OF SILLIMANITE FROM CLARENDON, SOUTH EASTERN ONTARIO

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MICROMEDIA

A STUDY OF THE BENEFICIATION OF A SAMPLE OF SILLIMANITE FROM CLARENDON, SOUTH EASTERN ONTARIO

by

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ABSTRACT

A sample of sillimanite ore from Clarendon, Ontario, estimated by X-Ray diffraction techniques to contain approximately 20% sillimanite was processed by sizing, air tabling, air classification, magnetic separation and flotation. The probable beneficiation treatment route likely to best concentrate the sillimanite ore is a combination of sizing, air classification and magnetic separation. No definite conclusions can be made with respect to optimum grade and recovery due to the limited, mainly qualitative, nature of this investigation. A combination of air classification and magnetic separation of a sized -600 +300 µm fraction produced a concentrate grading 56% sillimanite with a recovery of 58.5%, based on the -600 +300 µm feed fraction being 100%.

Keywords: Sillimanite, Mineralogy, Beneficiation, Flotation, Aspect ratio

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ÉTUDE DE L'ENRICHISSEMENT D'UN ÉCHANTILLON DE SILLIMANITE PROVENANT DE CLARENDON, DANS LE SUD-EST DE L'ONTARIO

par

P.R.A. Andrews* et W. Kelly**

RÉSUMÉ

Nous avons évalué un échantillon de sillimanite provenant de Clarendon, en Ontario, au moyen de techniques d'analyse aux rayons x. L'échantillon, qui avait une teneur en sillimanite d'environ 20 %, a été soumis à un traitement comprenant l'analyse granulométrique, la concentration sur table pneumatique, la séparation magnétique et la flottation. La meilleure technique pour concentrer le minerai de sillimanite est vraisemblablement celle qui combine l'analyse granulométrique, la classification pneumatique et la séparation magnétique. Il a été impossible de tirer des conclusions finales en ce qui concerne la qualité optimale et la récupération en raison de la nature limitée et principalement qualitative de l'étude. Une combinaison de la classification pneumatique et de la séparation magnétique d'une fraction de -600 +300 µm a permis d'obtenir un concentré ayant une teneur en sillimanite de 56 % et un taux de récupération de 58,5 % , en se fondant sur le fait que la fraction d'alimentation -600 +300 m est égale à 100 %.

Mots-clé: sillimanite, minéralogie, enrichissement, flottation, rapport

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INTRODUCTION

The Canada Centre for Mineral and Energy Technology (CANMET) was requested by SJB Geology Services, Toronto, Ontario to conduct a preliminary investigation on three grab samples (weighing = 6.5 kg) obtained from the Clarendon sillimanite occurrence. The purpose of the study was to assess the possibility of preparing refractory and filler-grade sillimanite; the latter requires sillimanite to have a high aspect ratio.

DEPOSIT LOCATION

The Claredon sillimanite occurrence is situated northwest of Little Green Lake, 4 km north of the Village of Ardock, Clarendon Township, Frontenac County, south-eastern Ontario. The site is approximately 240 km northeast of Toronto and 28 km northwest of Sharbot Lake. Access is by provincial secondary highways connecting to a network of tourist and logging roads giving direct access to the site.

GEOLOGY

The occurrence is located in the central metasedimentary belt of the Grenville Province [1]; metavolcanic and metasedimentary rocks underlie most of the area surrounding the site. Plutonic rocks lie northeast and southeast of the site. Metasediments of the Flinton group are found in narrow, northeasterly striking synforms, which are found running through the immediate site area[2-4].

The area of the Claredon sillimanite occurrence is dominated by three basic rock types; mafic to intermediate paragneisses, calcitic and dolomitic marbles and pelitic schist[5]. The samples received were obtained from a sub-unit referred to as the main central unit of the pelitic schist unit.

SAMPLE DESCRIPTION

The material as received is a pelitic porphyroblastic schist with the matrix displaying good foliation. Mineral composition is composed of

biotite and muscovite with well lineated parallel to foliated, 1-2 cm, elongated ellipsoids of sillimanite, anhedral garnet and porphyroblastists (blebs). Quartz, plagioclase feldspar and magnetite constitute the major part of the matrix assembly. The sillimanite crystal within these blebs are acicular with aspect ratios of between 20:1 and 30:1. Microscopic examination of these crystals has revealed that there is micro fracturing throughout the crystal lattice which results in the destruction of the high aspect ratio during comminution. The sillimanite crystals also are associated with minor amounts of interstitial grains of magnetite.

PROCESSING

Head sample

A representative portion of head material was sized on alternate screen sizes from 2.4 mm to 150 µm. Each fraction was analysed for sillimanite using a semi-quantitative X-Ray diffraction method; results are reported in Table 1.

Size reduction

The bulk sample was divided into two portions, Sample A and B. Each sample was then size-reduced to 6 mm by two comminution procedures to determine which procedure would least reduce the high aspect ratio. Sample A was crushed by a combination of jaw and roll crushing, and Sample B by hammer milling.

Each crushed product was examined by binocular microscope to determine the liberation size of the sillimanite, and the effect that the various types of crushing had on the aspect ratio of the sillimanite crystals. The size distribution of each crushed product is reported in Table 2, and the results of microscopic examination of size fractions from each crushed product in Table 3. After microscopic examination Samples A and B were recombined and further size-reduced to 600 µm.

Dry processing

A 1 kg portion of -600 + 210 µm material was passed over the Denver air table; the products were then assessed qualitatively for visible concentration of minerals.

Separate 1 kg portions of -600 +300 µm and -300 +150 µm fractions were processed in a laboratory zig-zag air classifier to separate the sillimanite from the lighter micaceous and other gangue minerals. The sillimanite rich sink fractions were further processed using a Perm-roll magnetic separator to remove magnetic material. The combined procedure is illustrated in Fig. 1.

The possibility of employing magnetic separation prior to air classification also was investigated using separate 1 kg portions of -600 +300 µm, and -300 +150 µm fractions. The combined procedure also is illustrated in Fig. 1.

The products of beneficiation were analysed by semi-quantitative X-Ray diffraction and the results of product balances are reported in Table 4.

Wet processing

The flotation of sillimanite was briefly investigated using 1 kg portions in a Denver D1 laboratory flotation cell. A 5 kg batch of feed material was passed over the Perm-roll magnetic separator to remove magnetic material, and the non-magnetic fraction divided into 1 kg portions. Flotation was conducted at pH 10.0 using sodium oleate collector with one cleaning stage. The product balance and reagent concentration data for the best test are reported in Table 5.

ANALYSIS PROCEDURE

Each sample was ground to -50 µm and scanned from 5 to 90° 2-theta at a scan speed of 10° per minute with a half of a degree step size on the Rigaku automated powder diffractometer at 55 Kv and 180 mA. Identification of peaks and search matching were performed using the PDP 11/73 computer with Rigaku qualitative software. Peak intensities of sillimanite and mica (phlogopite) lines were verified against standard mica and sillimanite.

Preparatory to the analysis of beneficiated sillimanite samples, a calibration curve was established based on varying mixtures of standard mica and sillimanite. The mica standard (Fig. 2) from the National Bureau of Standards, and the National Mineral Collection Sillimanite Standard (Fig. 2) from Beavertone, Ontario were mixed in three proportions (by weight) as follows:

30% mica / 70% sillimanite - Fig. 3
50% mica / 50% sillimanite - Fig. 4
70% mica / 30% sillimanite - Fig. 5

The relative intensity of the (120) line of sillimanite in each of the three mixtures was plotted against the analysis percent of sillimanite to establish the calibration curve (Fig. 6). The relative intensity of the (120) line of sillimanite in each of the unknown sillimanite products was then plotted on the graph to determine the analysis percent of sillimanite.

RESULTS

Mineralogy

The microscopic examination of sized products indicated that approximately 70 to 80% liberation of sillimanite occurred at 650 µm and that liberation was essentially complete at 300 µm. Minor magnetite inclusions, however, persisted down to 100 µm. There was no pronounced or apparent aspect ratio at any size.

Size reduction

Microscopic examination determined that there was no visible difference or benefit in either crushing method; each reduced the aspect ratio of the sillimanite.

Dry processing

Air tabling removed mica and biotite only to a limited extent; despite a high grade mica/biotite concentrate, the concentrate weight recovery was only 11.4%. Some of the results of the combined zig-zag air classification and magnetic separation tests in Table 4 indicate partial success in concentrating sillimanite. Sillimanite can be concentrated, but only with a low concentration ratio when -600 +300 µm material was processed by air classification prior to magnetic separation (Test 1). Magnetic separation prior to air classification conducted on the same size material (Test 2) was less effective in upgrading sillimanite. The results obtained with the -300 +150 µm fraction did not demonstrate that either beneficiation procedure could concentrate sillimanite. The best test, Test 1, conducted on -600 +300 µm material produced a sillimanite concentrate grading 56% with a recovery of 58.5%, based on the -600 +300 µm fraction feed material being 100%.

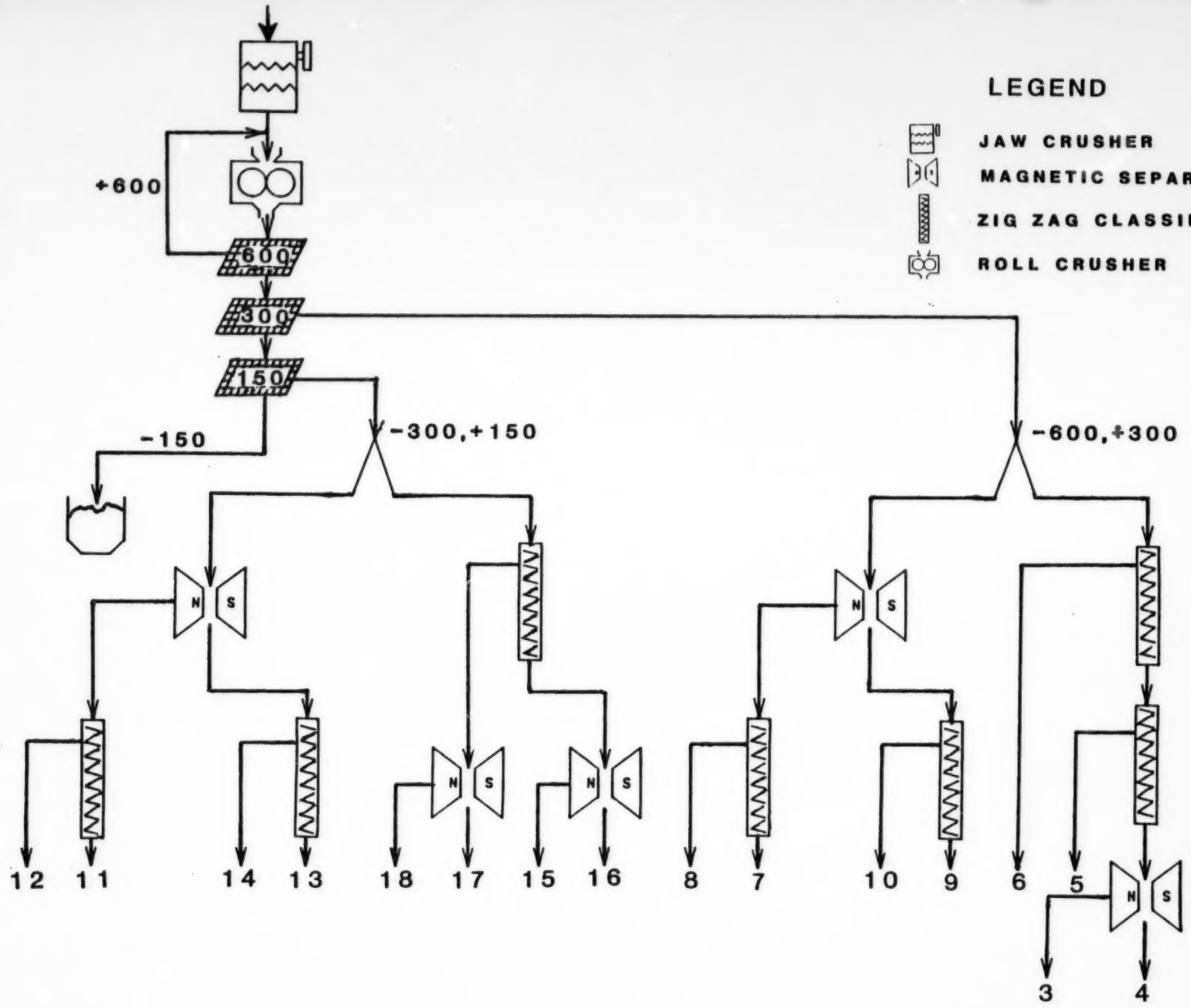

Fig. 1 Clarendon sillimanite flow diagram.

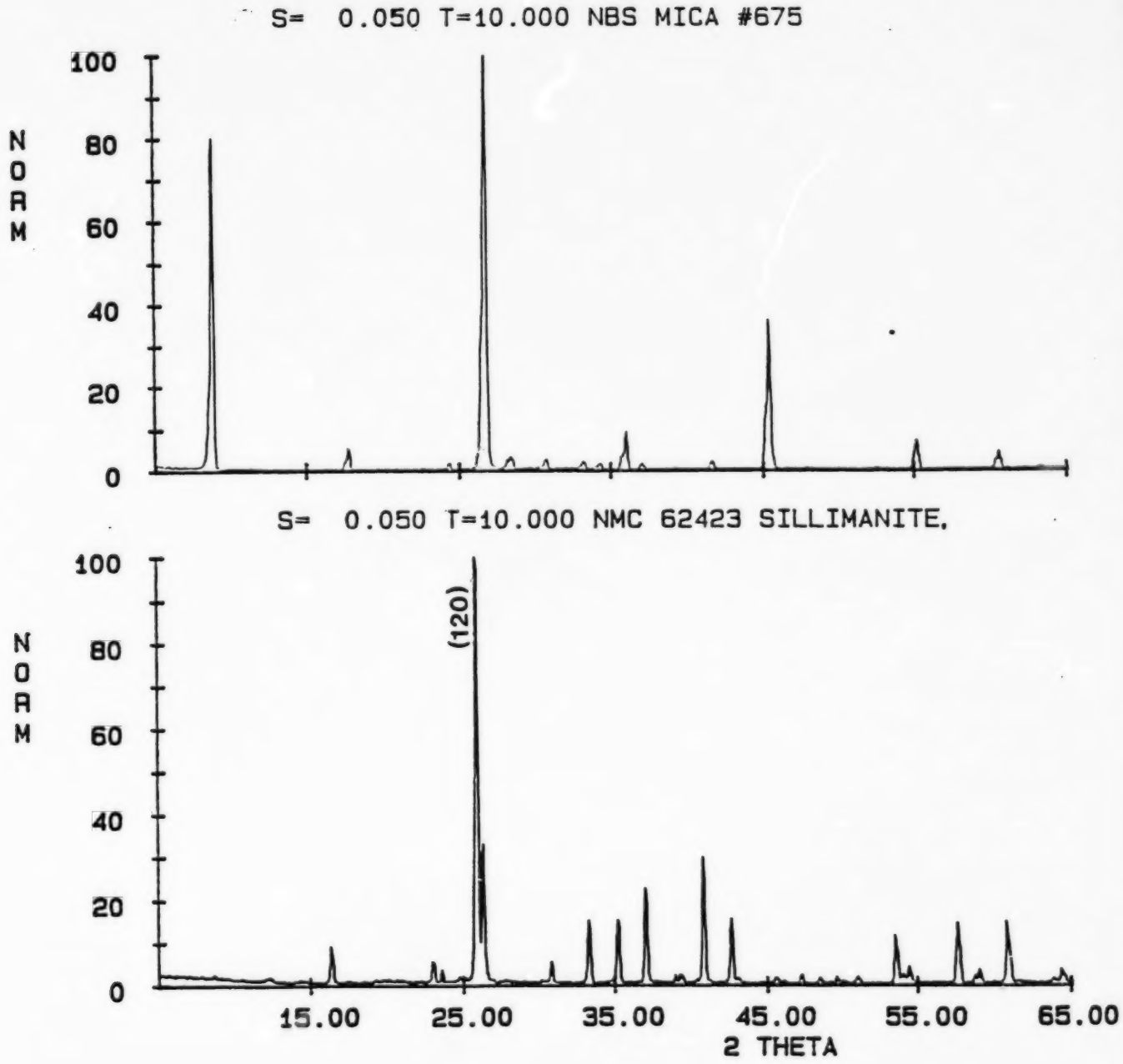

Fig. 2 X-ray diffraction powder patterns for standard mica and sillimanite

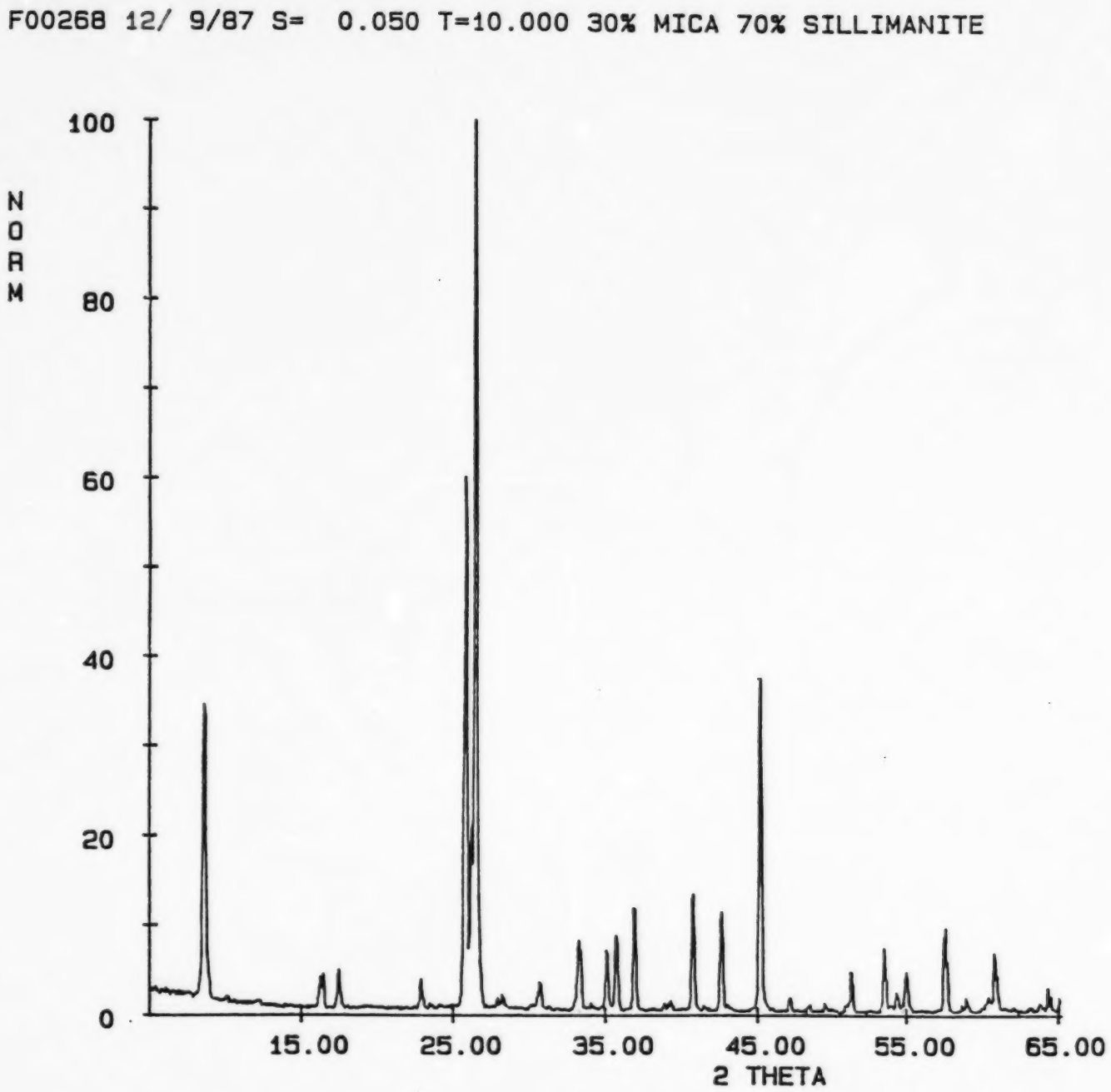

Fig. 3 X-ray diffraction powder pattern for a composite of 30% mica and 70% sillimanite

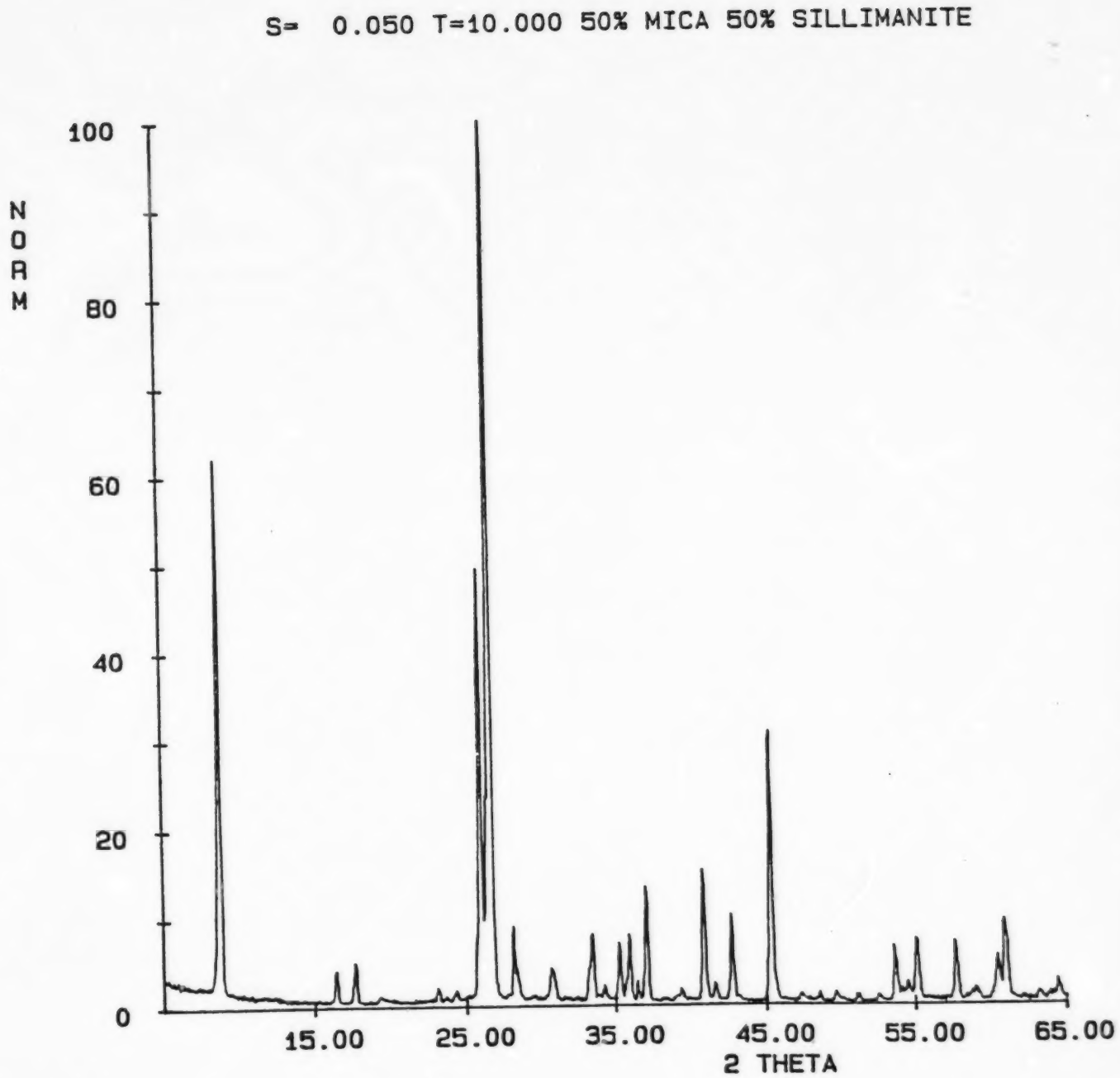

Fig. 4 X-ray diffraction powder pattern for a composite of 50% mica and 50% sillimanite

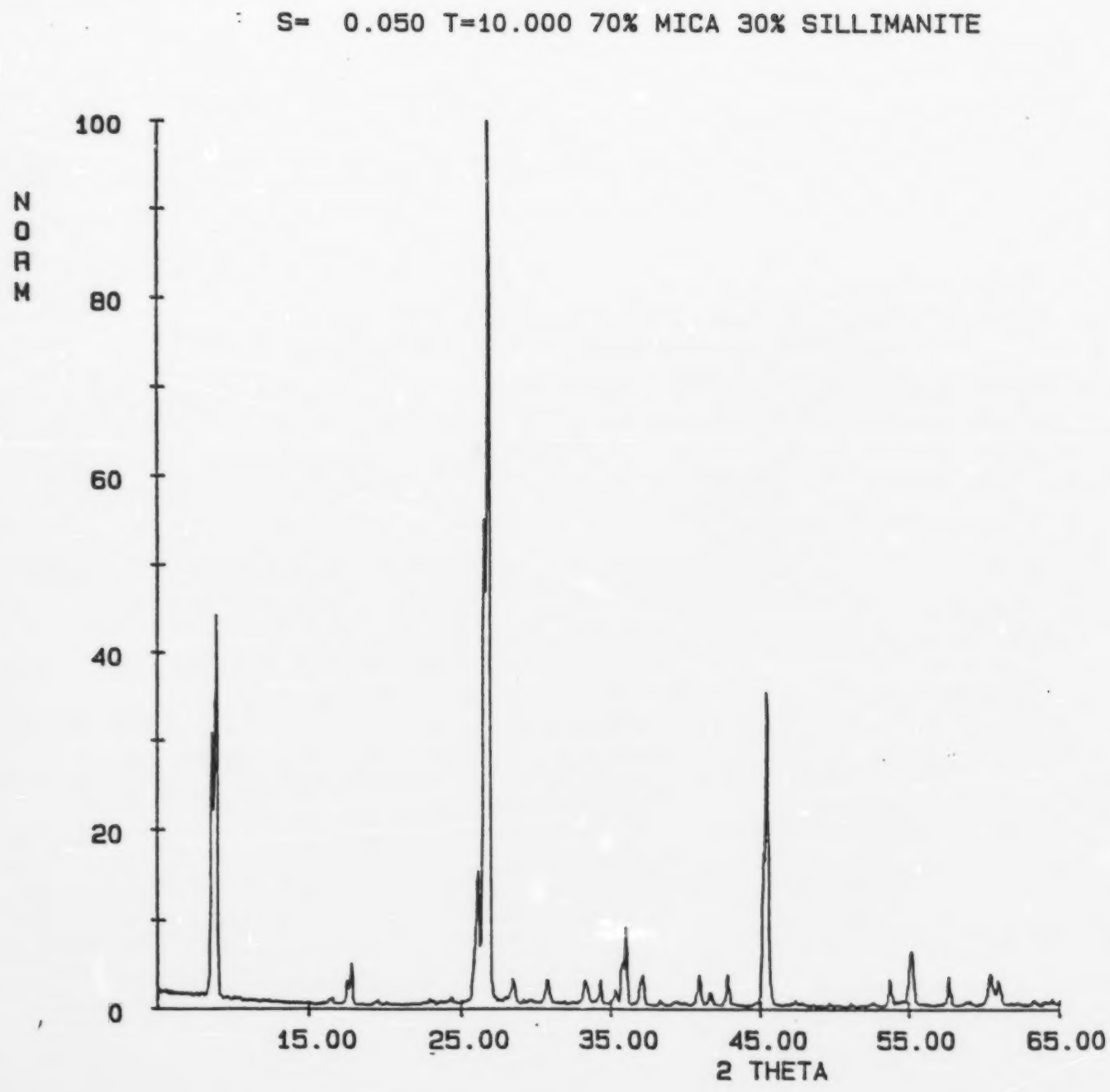

Fig. 5 X-ray diffraction powder pattern for a composite of 70% mica and 30% sillimanite

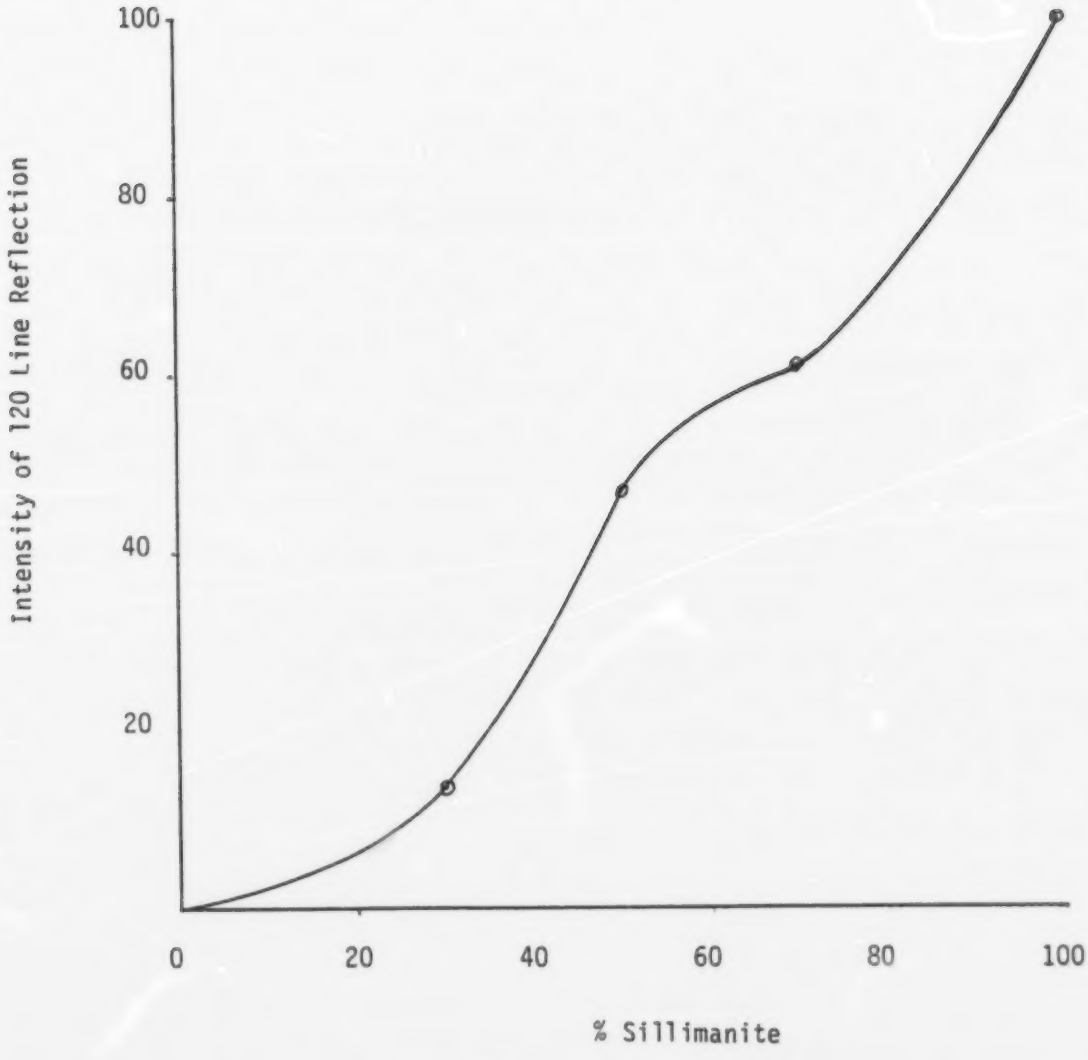

Fig. 6 Calibration curve relating the relative intensity of the 120 sillimanite line with sillimanite grade of an unknown product.

Wet processing

A preliminary flotation evaluation produced a concentrate grading 52% sillimanite for a recovery of 40.7%, based on feed to flotation being 100%.

CONCLUSIONS

The study indicates that sillimanite from Clarendon can only be beneficiated to a limited extent by a combination of prior air classification followed by magnetic separation using -600 +300 µm material. No definite conclusions regarding optimum grade and recovery of sillimanite can be made due to the limited, largely qualitative, nature of the investigation.

RECOMMENDATIONS

Further testwork at the laboratory and possibly pilot-plant level should be conducted to establish a more selective beneficiation procedure. If sillimanite from Clarendon can be beneficiated to the extent required for its various uses then the following recommendations would apply:

1. A market study should be conducted to establish size and variety of markets, competition from substitute materials, and product specifications and requirements pertaining to the type and percentage of acceptable deleterious material.

2. Cost benefit analysis should be conducted to establish cut-off grade.

3. Additional diamond drilling should be undertaken to determine ore grade and extent of the deposit.

4. A product evaluation should be carried out.

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Table 1. Head sample sillimanite distribution

Size µm	Analysis % Sillimanite
+2400	25
-2400 +1200	32
-1200 + 600	23
- 600 + 300	12
- 300 + 210	7
- 210 + 150	9
- 150	20

Table 2. Size distribution of crushed products from Sample A and B

Size µm	Sample A % Wt	Sample B % Wt
+2380	41.1	46.1
-2380 +1190	21.3	13.6
-1190 +590	10.1	11.4
-590 +300	10.1	12.8
-300 +210	4.8	6.1
-210 +150	3.7	4.0
-150	8.9	6.0
TOTAL	100.0	100.0

Table 3. Binocular microscopic examination of sized fractions of samples A and B

	Description
+2380	- compound grains of biotite, muscovite, quartz, sillimanite garnet, magnetite, plagioclase; minor limonitic staining on some grains; minor trace of sulphides (pyrite) - visible separation of porphyroblastic sillimanite blebs from compound mica aggregate - sillimanite has no visible aspect ratio or acicular shape, grains fairly blocky and massive.
-2380 +1190	- same as for +2380 µm fraction with minor liberation; interstitial magnetite grains are quite visible in the sillimanite crystal aggregates
-1190 +590	- same as the -2380 +1190 µm fraction, through liberation is now fair; magnetite inclusions still persist.
-590 +300	- good liberation of sillimanite with minor liberation of the magnetite inclusion
-300 +210	- complete sillimanite liberation with fair liberation of the magnetite inclusions
-210 +150	- minor magnetite inclusions in sillimanite crystals
-150 +100*	- same as for the -210 +150 µm fraction; minor aspect ratio evident, approximately 1-5% displaying a ratio from 3:1 to 6:1
-100 +44*	- complete liberation from magnetite

* Prior wet screening to remove fines.

Table 4. Combined Zig-Zag air classification and magnetic separation results

Test No.	Products	Actual Wt %	Relative Wt %	Analysis % sillimanite	Distribution % actual	Distribution % relative
	+600 µm					
	Magnetics	0.4	21.8	7	0.1	9.0
	Non-magnetics	1.5	78.2	19	1.1	91.0
	Head calculated	1.9	100.0	17	1.2	100.0
	-600 +300 µm					
1.	Floats #1	1.0	4.7	-	-	-
	Floats #2	1.1	4.9	7	0.3	1.1
	Sinks, magnetics	12.6	56.6	23	10.9	40.4
	Sinks, non-magnetics	7.5	33.8	56	15.9	58.5
	Head calculated	22.2	100.0	32	27.1	100.0
2.	Magnetics, floats	2.4	10.7	-	-	-
	Magnetics, sinks	12.1	54.6	30	13.7	50.8
	Non-magnetics, floats	0.2	1.1	31	0.2	0.9
	Non-magnetics, sinks	7.5	33.6	46	13.0	48.3
	Head calculated	22.2	100.0	32	26.9	100.0
3.	-300 +150 µm					
	Floats, magnetics	2.4	17.1	10	0.9	6.3
	Floats, non-magnetics	1.3	9.1	43	2.1	14.7
	Sinks, magnetics	5.1	36.7	21	4.0	28.1
	Sinks, non-magnetics	5.1	37.1	38	7.3	50.9
	Head calculated	13.8	100.0	28	14.3	100.0
4.	Magnetics, floats	4.2	30.3	16	2.5	18.5
	Magnetics, sinks	3.2	23.2	30	3.6	26.5
	Non-magnetics, floats	1.9	14.0	34	2.4	17.8
	Non-magnetics, sinks	4.5	32.5	30	5.1	37.2
	Head calculated	13.8	100.0	26	13.6	100.0
	-150 µm	26.1	-	17	16.9	-
	TOTAL	100.0	-	26.5	100.0	-

Table 5. Flotation product balance and reagent concentration data

Products	Weight %	Analysis % sillimanite	Distribution %
Final concentrate	32.5	52	40.7
Cleaner tails #1	10.8	44	11.5
Rougher tails	56.7	35	47.8
Head calculated*	100.0	42	100.0

Rougher flotation time	6 min
Cleaner flotation time	2 min
Rougher pH	10.0
Cleaner pH	10.0
Rougher collector concentration	1622 g/t
Cleaner collector concentration	464 g/t
Frother	M.I.B.C.

* Prior to flotation the -150 µm material was removed by sizing; magnetic material also was removed, consequently, the actual weight percent of feed to flotation was 27.7.